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(71) Applicant
British Aerospace Public Limited Company

(Incorporated in the United Kingdom)

11 The Strand, London, WC2N 5JT, United Kingdom

(72) Inventor
Peter Roy Gilmour

(74) Agent and/or Address for Service
Susan Patricia Potts
British Aerospace Public Limited Company,
PO Box 87, Company Headquarters, Royal Aerospace Establishment, Farnborough, Hants, GU14 6YU, United Kingdom

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(56) Documents cited
GB 2196735 A GB 2056672 A WO 88/05529 A1
WO 83/00744 A1

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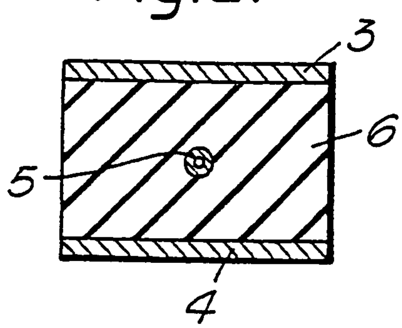
WPI

(54) **Weighing apparatus for vehicles**

(57) A fibre optic cable 5 whose light transmission characteristics vary under load is encased in a pressure pad of resilient material 6 and laid across a roadway. As a vehicle crosses the pressure pad, a time domain reflectometer calculates the load exerted by each wheel by monitoring the intensity of back scattered light from the fibre optic cable 5. The invention has the advantage of simplicity, portability and the ability to weigh and detect vehicles in motion.

Fig. 2.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

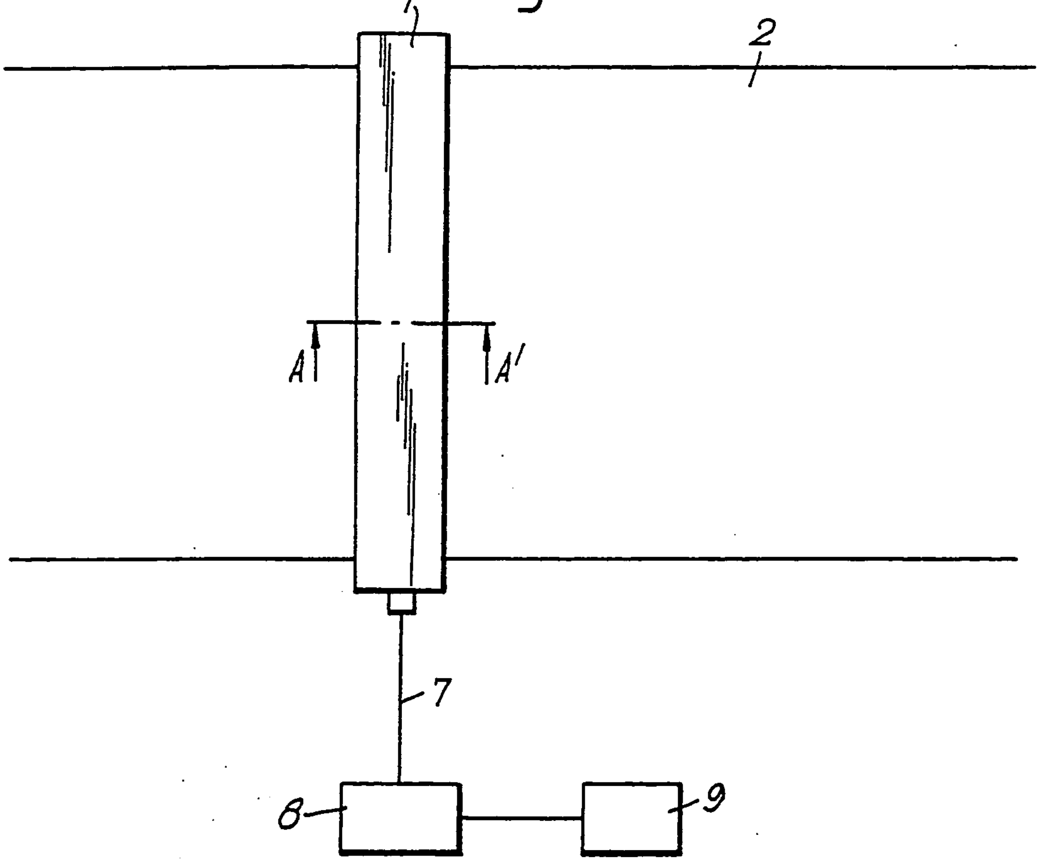


Fig.2.

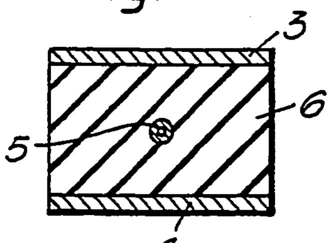


Fig. 3.

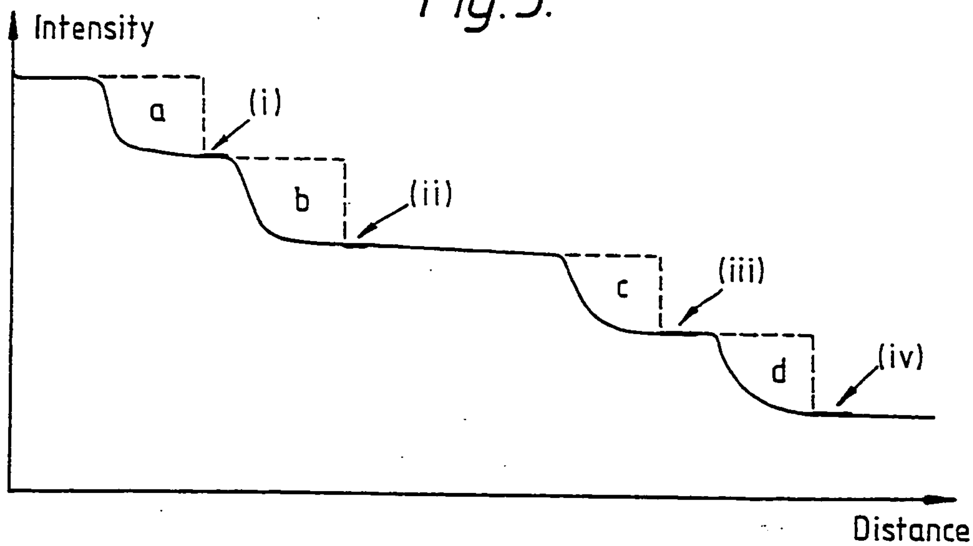


Fig. 4A.

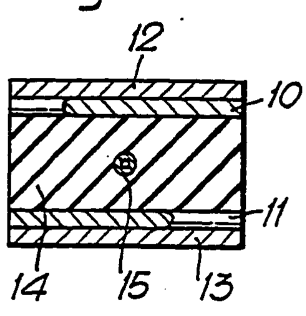


Fig. 4B.

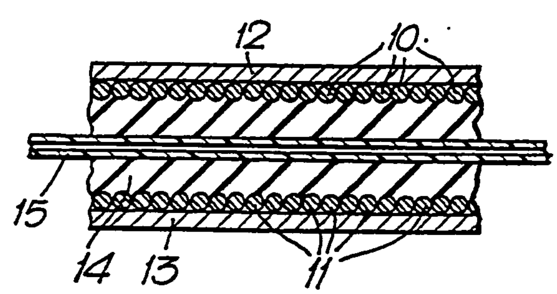


Fig.5A.

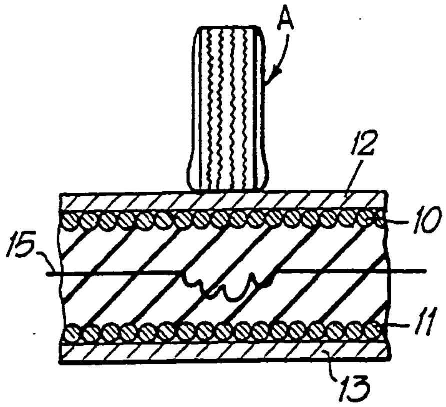


Fig.5B.

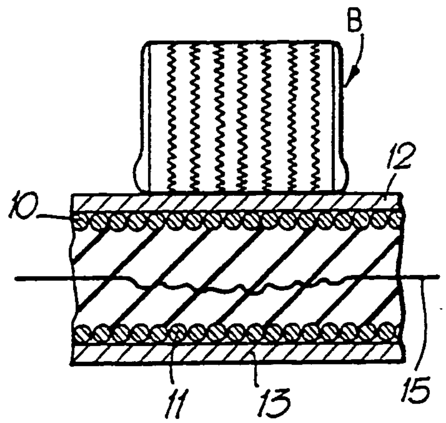


Fig.6A.

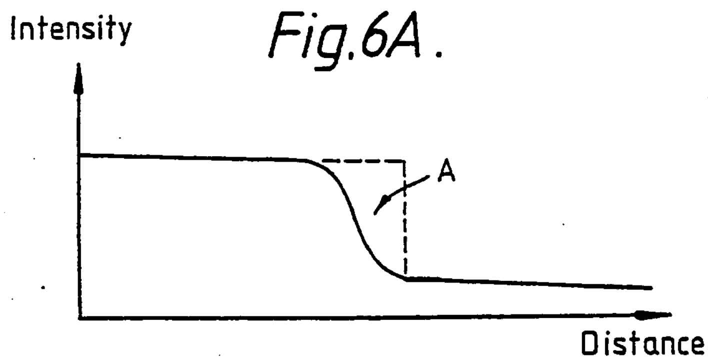
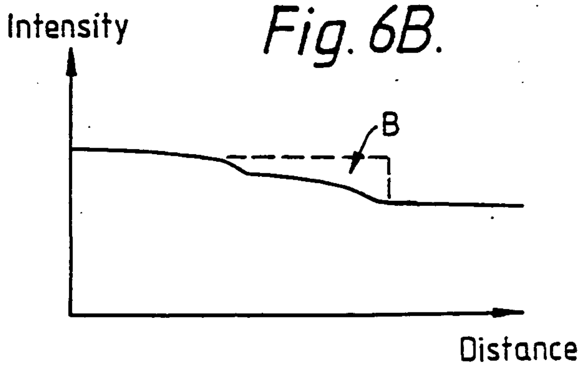


Fig.6B.



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WEIGHING APPARATUS FOR VEHICLES

This invention relates to apparatus for weighing vehicles, said apparatus comprising an optical transducer whose properties vary as the transducer is stressed under load.

One known weighing apparatus of this type is described in WO89/02584. This comprises a plate structure embodying a light transmitting medium, a polarised light source and a polariser and detector to detect light emerging from the medium. The polarisation of the light travelling through the medium is altered in a manner dependent on the load exerted on the plate.

This apparatus is inherently complicated as it comprises many optical components. A further disadvantage is that one plate is required for each wheel of the vehicle to be weighed.

An object of this invention is to provide a weighing apparatus which has a minimum of components and is therefore cheap to manufacture and in which only one sensor is required for weighing vehicles irrespective of the number of wheels or axles that the vehicle has.

A further object of the invention is to provide a weighing apparatus which is operable when the vehicle is in motion.

In order to achieve these objects (and certain advantages to be described below) the invention employs the principles of optical time domain reflectometry.

Optical time domain reflectometry was devised by Barnoski et al (see Applied Optics 1976 Vol 15 pp. 2112 - 2115). The earliest systems utilised an optical radar concept to examine the continuity and attenuation of fibre optic cables from a measurement of the back scattering against time characteristics when a short pulse of light was launched into a fibre. Optical time domain reflectometers are currently used extensively for detection and location of faults (for example breaks and bends) in fibre optic cables. The distance "D" to a fault is given by

$$D = \frac{ct}{2n}$$

where 'c' is the speed of light in the cable, 't' is the observed time between the pulse launch and reception of the return signal and 'n' is the effective index of refraction of the cable's core.

Further details of the operation and applications of optical time domain reflectometers can be found in Electro-Optical Systems Design: April 1981 pp 47-52 and in J. Phys.E.Scientific Instruments Vol 20 pp 954-966.

According to this invention a weighing apparatus for a vehicle comprises:

an optical transducer whose light transmitting properties vary as a load is applied thereto;

a light source for transmitting a modulated light signal through the optical transducer;

a receiver for measuring the intensity of a light signal reflected by the optical transducer;

means for calculating the magnitude of an applied load from calibration data relating load to reflected light intensity;

and in which the optical transducer is located within a block of resilient material for placement under the wheel(s) of the vehicle.

Just one optical transducer is required for measurement of a vehicle's weight, irrespective of the number of wheels on the vehicle.

A further advantageous feature of the invention is its portability.

The modulated light signal may be a train of light pulses, for example.

The optical transducer may be a fibre optic cable. In this case, as the resilient block deforms under load, it causes the fibre optic cable to bend. The amount of bending is a function of the load applied and manifests itself as a variation in reflected light intensity.

The block of resilient material may be housed for protection between upper and lower plates made from a rigid material such as steel or titanium.

Preferably the block and upper and lower plates are located in a protective housing which provides thermal insulation and which is watertight.

The upper plate or the upper and lower plates may incorporate a corrugated region. The corrugations serve to control the bending of the fibre optic cable so that the measured reflected light intensity is not dependent on the width of the vehicle wheel incident on the upper plate.

Some embodiments of the invention will now be described, by way of example only, with reference to the drawings of which:

Fig 1 is a plan view of a weighing apparatus in accordance with the invention;

Fig 2 is a section along a line A-A' of Fig 1;

Fig 3 is a graph of distance along a light transmitting fibre optic cable versus reflected light intensity;

Figs 4A and 4B are respectively transverse and longitudinal cross-sectional views of one form of pressure plate incorporating the invention;

Figs 5A and 5B show the operation of the pressure plate of Figs 4A and 4B when loaded by wheels of different widths; and

Figs 6A and 6B are graphs of distance along a light transmitting fibre optic cable versus reflected light intensity under the conditions of operation illustrated in Figs 5A and 5B respectively.

In Fig 1 an optical pressure plate 1 is laid across a road 2 (or railway or runway) in the path of any vehicle travelling along the road 2. The optical pressure plate 1, (shown in cross-section in Fig 2) comprises top and bottom metal plates 3, 4 and a single fibre optic cable 5 embedded in a rubber block 6. The block 6 completely fills the gap remaining between the metal plates 3 and 4 and has known compression characteristics. Referring back to Fig 1, the fibre optic cable 5 has a section 7 which extends beyond the pressure plate 1 and connects with an optical time domain reflectometer 8 (OTDR). The OTDR 8 is controlled by a microprocessor 9. The depth of pressure plate 1 is such that a vehicle may be easily driven across it and its width is made sufficient to accommodate the complete footprint of a vehicle's wheel (or tyre).

The OTDR 8 and microprocessor 9 could be operated close to the pressure plate 1 or remotely as convenient. A remote location merely requires extending the section 7 of the fibre optic cable 5.

In an alternative embodiment the pressure plate 1 is positioned underneath yet close enough to the surface of the road in order to function satisfactorily.

The invention relies on reflected light intensity measurements for its operation. As each wheel of a vehicle to be measured crosses the pressure plate 1, the pressure exerted by each wheel causes the fibre optic cable 5 to bend. Consequently, a proportion of light directed along the core of the cable 5 from the OTDR8 will be reflected back to the OTDR8 from the region of cable 5 where the bend is located.

The amount of light lost is a function of the degree of bending to which the fibre optic cable 5 is subjected, and in turn, a function of the local load placed on the pressure plate 1.

The load exerted by each wheel as it crosses the pressure plate 1 is, of course, a proportion of the total weight of the vehicle. By summing the loads exerted by each wheel, the total vehicle weight is calculated. The microprocessor 9 is programmed to perform this calculation.

Calculation of total vehicle weight will now be described with reference to Fig 3. Fig 3 shows how the intensity of the back scattered light detected by the OTDR8 varies with distance along the fibre optic cable 5.

In the example of Fig 3 a four-wheeled axle has crossed the pressure plate 1 causing the fibre optic cable 5 to bend at four locations underneath each wheel. As a result, the back scatter picture (curve A of Fig 3) is produced by the OTDR 8. Curve A can be divided up into four distinct areas

due to the effect of each wheel on the fibre optic cable 5. These four areas are designated a, b, c and d. Dividing the four areas are points of zero gradient shown at (i), (ii), (iii) and (iv) on Fig 3. The areas a, b, c and d are calculated by the microprocessor 9 and stored. A similar curve is obtained for subsequent axles of the vehicle and the total weight of the vehicle is calculated by summing the contributions from each wheel. The microprocessor 9 has access to a predetermined calibration plot comprising a weight versus area graph, thus enabling it to relate the back scatter picture to the total vehicle weight.

It will be appreciated from the foregoing that the weight of a vehicle can be calculated as it is travelling along the road 2. Furthermore the invention will perform satisfactorily independently of the angle at which the vehicle's tyres cross the pressure plate 1. The invention will give a true reading of vehicle weight irrespective of whether or not all the wheels on one axle of a vehicle cross the pressure plate 1 simultaneously. This advantage could not be achieved by using a simple power meter in place of an OTDR.

The intensity of the light lost from the fibre optic cable is related to the angle that the fibre is bent. To ensure that the fibre optic cable has enough bends to lose the correct amount of light for wheels that have the same weight but are of different area, an alternative form of

pressure plate is employed (see Fig 4A and Fig 4B). Here, two series of metal rods 10 and 11 are located in contact with two metal end plates 12, 13 and embedded in a rubber block 14. A fibre optic cable 15, also embedded in the rubber block 14 distorts in the manner shown in Figs 5A and 5B when tyres A and B of different surface area are incident on the upper metal plate 12. It is assumed that the two tyres A and B exert equal force on the fibre optic cable 15.

As wheel B crosses the metal plate 12 although of the same weight as wheel A, this weight is spread over a larger area. It can be seen from Figs 5A and 5B that although a larger length of fibre optic cable 14 is affected by wheel B, the bends are less severe and the light lost from the affected length of fibre produces a different graph on the OTDR/Processor network, but the relevant area of the graph is the same as for wheel A. I.e. area A is equal to area B on Figs 6A and 6B.

Therefore, although different graphs are produced, the loads exerted by wheels A and B will be calculated by the microprocessor 9 to be equal.

In addition to the weighing of vehicles, the invention can be used for detection of vehicles on a highway thus monitoring road traffic, for example, as part of a traffic control system.

It can also be used for determining the number of wheels on a vehicle as it crosses the pressure plate.

The invention could find application at airports for determining the centre of gravity of aircraft. This information is useful for ensuring that aircraft are correctly loaded.

CLAIMS

1. A weighing apparatus for a vehicle comprising:

an optical transducer whose light transmitting properties vary as a load is applied thereto;

a light source for transmitting a modulated light signal through the optical transducer;

a receiver for measuring the intensity of a light signal reflected by the optical transducer;

means for calculating the magnitude of an applied load from calibration data relating load to reflected light intensity;

and in which the optical transducer is located within a block of resilient material for placement under the wheels(s) of the vehicle.

2. A weighing apparatus according to claim 1 in which the optical transducer is a fibre optic cable.

3. A weighing apparatus according to claim 1 or claim 2 in which the block of resilient material is made from rubber.

4. A weighing apparatus according to any preceding claim in which the block of resilient material is housed between two plates, said plates being made from a substantially rigid material.

5. A weighing apparatus according to claim 4 in which one of the plates incorporates a corrugated region.

6. A weighting apparatus according to any preceding claim in which the modulated light signal is a train of pulses.

7. A weighing apparatus substantially as hereinbefore described with reference to the drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number	
	9027214.

Relevant Technical fields		Search Examiner
(i) UK Cl (Edition K)	G1A (ADE)	S J L Rees
(ii) Int Cl (Edition 5)	GOIG, GOIL	
Databases (see over)		Date of Search
(i) UK Patent Office		8.3.91
(ii)	WPI	

Documents considered relevant following a search in respect of claims ALL CLAIMS

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X,Y	GB 2056672 A (GEC) - see page 1, lines 42-45 lines 57-59, lines 66-85	1-6
Y	GB 2196735 A (BABOCK & WILCOX) - see page 1 lines 75-96 and Figure 1	1-6
Y	WO 88/05529 A1 (PFISTER) - whole document	1-6
Y	WO 83/00744 A1 (TRW) - see page 4 line 20 - page 5 line 1, page 5 line 21 - page 6 line 8	1-6

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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